OKU Fen Bilimleri Enstitüsü Dergisi
6(1): 585-593, 2023

OKU Journal of The Institute of Science and Technology, 6(1): 585-593, 2023

Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi

Osmaniye Korkut Ata University Journal of The Institute of Science and Technology

İspir ve Kızılcahamam Kuru Fasulyesi için Gama Işını Lineer Soğurma Katsayıları ile Transmisyon Faktörlerinin Ölçülmesi Üzerine Deneysel Bir Çalışma

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Araştırma Makalesi

Makale Tarihçesi:
Geliş tarihi:02.03.2022
Kabul tarihi:05.09.2022
Online Yayınlanma: 10.03.2023

Anahtar Kelimeler:
Türkiye
IDB
KDB
TF
EDXRFS

ÖZ

Bu çalışmada, Erzurum İspir kuru fasulyesi ve Ankara Kızılcahamam kuru fasulyesi için gama ışını lineer soğurma katsayıları (µ) ve transmisyon faktörleri (TF) ölçülmüştür. Deneyde Am-241 nokta kaynağının 59,54 keV enerjili fotonları, Energy Dispersive X-Ray Floresans Spektrometrisi (EDXRFS) ve bir Si (Li) detektörü kullanılmıştır. Sonuç olarak, Erzurum İspir kuru fasulyesinin ortalama transmisyon faktörünün, Ankara Kızılcahamam kuru fasulyesininkinden daha büyük, ortalama lineer soğurma katsayısının ise daha küçük olduğu gözlenmiştir. Bu durum, Ankara Kızılcahamam kuru fasulyesinin, Erzurum İspir kuru fasulyesinden daha fazla gama ışını soğurduğu, yani gama ışınları ile daha fazla etkileşime girdiği anlamına gelmektedir.

An Experimental Study on the Measurement of Gamma-Ray Linear Attenuation Coefficients with Transmission Factors for Ispir and Kızılcahamam Dry Bean

Research Article

Article History:
Received:02.03.2022
Accepted: 05.09.2022
Published online: 10.03.2023

Keywords:
Turkey
IDB
KDB
TF
EDXRFS

ABSTRACT

In the present work, the gamma-ray linear attenuation coefficients (µ) and transmission factors (TF) were measured for Erzurum Ispir dry bean (IDB) and Ankara Kızılcahamam dry bean (KDB). Photons of the Am-241 point source with an energy of 59.54 keV, an Energy Dispersive X-Ray Fluorescence Spectrometer (EDXRFS), and a Si (Li) detector were used in the experiment. As a result, it was observed that the average transmission factor of Erzurum İspir dried beans was higher than that of Ankara Kızılcahamam dry beans, and the average linear attenuation coefficient was smaller. This means that Ankara Kızılcahamam dry beans absorb more gamma rays than Erzurum İspir dry beans, that is, they interact more with gamma rays.

To Cite: Akça B. İspir ve Kızılcahamam Kuru Fasulyesi için Gama Işını Lineer Soğurma Katsayıları ile Transmisyon Faktörlerinin Ölçülmesi Üzerine Deneysel Bir Çalışma. Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi 2023; 6(1): 585-593.

1. Introduction

Dry bean is produced in many countries due to being a cheap protein source, supplying the nutritional needs of the population, providing the livelihood of the rural population, taking place in the traditional culinary cultures of especially Latin American countries, and being subject to international trade. Dry beans, which have an important place in Turkish cuisine, are consumed at a rate of 24% among legumes. Central Anatolia Region meets the majority of dry bean production in Turkey.

It is also very important to protect the bean, which is an important food source, without spoiling. Foodstuffs can spoil for a variety of reasons (eg. biological, chemical and physical factors). Various food preservation methods have been developed to eliminate the factors that cause spoilage (eg. drying, heat treatment, fermentation, salting, smoking, canning, freezing, refrigerated storage, and chemical treatment). Studies on the development of new methods that reduce losses in food production, extend shelf life, and ensure food safety are continuing. Food irradiation, which is one of the methods that has been studied extensively in recent years, is a method that can meet these expectations and its use is becoming increasingly widespread (Lacroix and Ouattara, 2000; ACSH, 2003; Atasever and Atasever, 2007).

Radioactive materials emit some rays (eg. alpha, beta, gamma, and X-rays) to the environment during the continuous disintegration of their atoms. These rays cause electrically charged ions in the material they hit. These rays are called ionizing rays. Ionized beam; non-ionizing visible light has more energy than television and radio waves and microwaves. Food irradiation; is the treatment of food with ionizing rays, also called ionized energy (WHO 1983; ADA 2000; Lacroix and Ouattara, 2000).

Gamma rays, X-rays, and accelerated electron beams are used in food preservation [Olson, 1998]. Gamma rays are the most widely used in industry (WHO 1983; ADA 2000; Diehl, 1995; Swallow, 1991). Gamma rays are produced from Co^{60} and Cs^{137}. The rays are directly on the food to be irradiated given. But food should never come into direct contact with cobalt or cesium (Swallow, 1991; Diehl, 1995; Lagunas, 1995; Monk et al., 1995; ADA 2000; Lacroix and Ouattara, 2000). While some foods can be irradiated, some foods are not suitable for irradiation due to reasons such as losing their firmness and some important sensory and other quality properties. There is a green radura mark on irradiated packaged foods. Co^{60} and $Cs^{137}$are high-energy gamma sources. Their dose rates have been quite large compared to the gamma source in our study. No matter how innocent food irradiation is, it raises doubts about the effects of ionizing radiation on DNA are taken into account.

Cross sections, attenuation, and scattering coefficients play an important role in better explaining the absorption and scattering phenomena that occur as a result of the interaction of matter and electromagnetic radiation. Gamma-ray transmission factors and linear attenuation coefficients are measured to determine the level of gamma-ray and matter interaction and to obtain information at the atomic and molecular level of the material. These measurements appear in important application areas such as industrial, biological, and agricultural applications, dosimetry, radiography, and computed tomography. They are used in many processes such as multi-phase flow composition measurements in oil wells, thickness measurements for aluminum and steel production, bone density measurements, and soil density determination (Moss et al., 2013).

This study aims to determine how much radiation dry beans absorb as a result of their interaction with low-energy gamma rays. Thus, it will be observed how much radiation is left in the food and how much has passed. In other words, the rate of interaction with gamma rays will be investigated.

2. Material and Method

2.1. Theoretical Basis

The μ (cm^{-1}) can be derived from the Lambert-Beer law;

$$\mu = \left[\frac{\ln(I_0/I)}{t}\right] \tag{1}$$

where I_0 and I are the unattenuated and attenuated photon intensities, respectively, and t (cm) is the thickness of the material. The (TF) for material is determined as follows (Turhan et al., 2020):

$$TF = \frac{I}{I_0} x100 \tag{2}$$

2.2. Experimental Basis

In the experiment, first of all, narrow beam geometry or experimental setup was created using collimators. Thus, the beam is provided to follow a parallel path. The experimental setup used is shown in Figure. 1. Gamma-rays of Am-241 (100 mCi) point source were detected by using a high-resolution Si(Li) detector and Energy Dispersive X-Ray Fluorescence Spectrometer (EDXRFS). The data were collected into 4096 channels of a multichannel analyzer and the spectra were collected for 5400 s. The thickness of the samples is in the range of 5.72-8.82 mm. The typical spectra of 59.54 keV gamma-ray transmissions through KDB-2 are shown in Figure 2. Experimental errors are attributed to the deviation from the average value in the I and I_0 (<0.9%), sample thickness (<0.5%), the mass of the sample (<0.8%), and systematic errors (<1%).

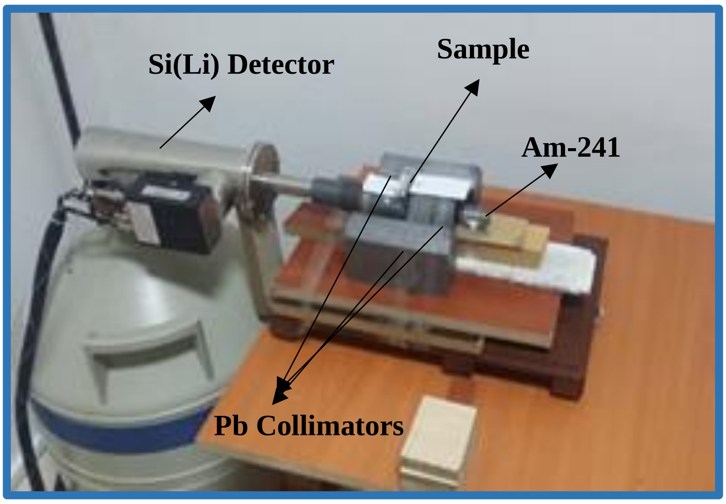

Figure 1. Experimental setup

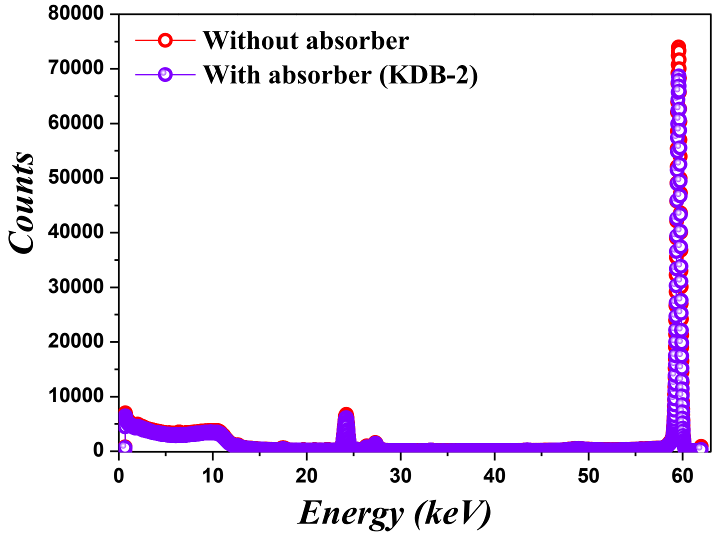

Figure 2. A typical spectrum for KDB-2

3. Results and Discussion

The TF, μ, and standard error values ($\pm\sigma_{\bar{x}}$) for IDB and KDB are given in Table 1. Transmission factors and linear attenuation coefficients for IDB and KDB are shown in Figures 3-4. Ten samples were randomly selected from both dry beans. Samples are numbered sequentially for graphs and tables.

Table 1. The TF, μ, and $\sigma_{\bar{x}}$ values for IDB and KDB

SAMPLES	***TF***	**μ (cm^{-1})**
IDB		
IDB-1	86.51555±0.40865	0.19210±0.00651
IDB-2	87.78976±0.27433	0.15959±0.00308
IDB-3	88.15452±0.23588	0.16546±0.00370
IDB-4	89.41329±0.10320	0.12687±0.00037
IDB-5	90.63398±0.02548	0.12906±0.00014
IDB-6	91.02792±0.06700	0.14200±0.00123
IDB-7	88.64612±0.18406	0.13981±0.00100
IDB-8	95.26803±0.51395	0.06345±0.00705
IDB-9	95.33851±0.52138	0.06167±0.00724
IDB-10	91.13528±0.07832	0.12344±0.00073
KDB		
KDB-1	85.60381±0.46154	0.20781±0.00548
KDB-2	92.77067±0.29391	0.13119±0.00260
KDB-3	94.71292±0.49864	0.08733±0.00722
KDB-4	93.26606±0.34613	0.10074±0.00581
KDB-5	92.59606±0.27550	0.11279±0.00454
KDB-6	88.77464±0.12731	0.17207±0.00171
KDB-7	86.80039±0.33541	0.21712±0.00646
KDB-8	89.53528±0.04713	0.17829±0.00237
KDB-9	88.88377±0.11581	0.16644±0.00112
KDB-10	86.88046±0.32697	0.18456±0.00303

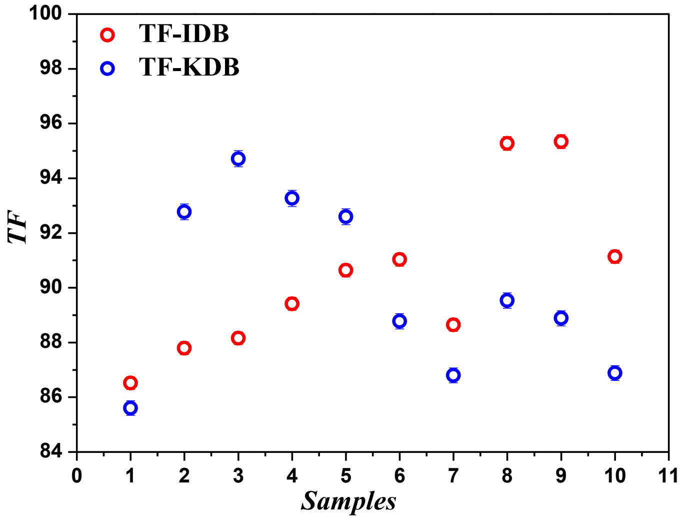

Figure 3. Gamma-rays Transmission factors versus samples

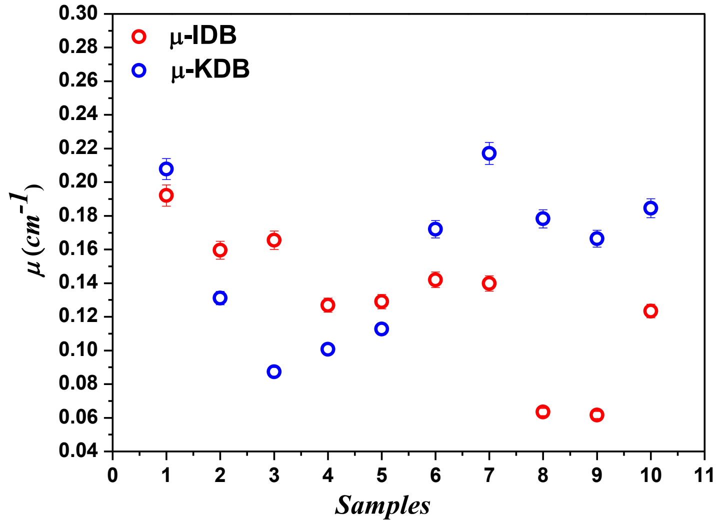

Figure 4. Gamma-rays Linear attenuation coefficients versus samples

When Table 1 and Figures 3-4 are examined, it is seen that TF and μ values for IDB and KDB are close. The average TF and μ values are 90.39230 and 0.13035 cm^{-1} for IDB and 89.98241 and 0.15583 cm^{-1} for KDB, respectively. KDB has absorbed about 11% of gamma-ray and passed 89%, while IDB has absorbed about 10% and passed 90%. According to these results, KDB is more absorbent. In other words, it interacted more with gamma rays. When exposed to gamma-ray treatment, KDB will contain more gamma rays. In a similar study by (Ghosh and Das, 2014), the linear attenuation coefficients of different varieties of potato (Kufri Chandramukhi, Kufri Jyoti, and Kufri Sindhuri), mango (Himsagar, Langra, Dashehri, and Fazli)) and prawn (Tiger prawn and Freshwater prawn) at different storage times and physiological stages at 2.5 MeV gamma energy were determined. Linear attenuation coefficient values were measured between 0.035-0.079 cm^{-1}. The lowest value of the linear attenuation coefficient was obtained in the Kufri Sindhuri variety of the potato, it received its greatest value in the Fazli variety of mango. As the linear attenuation coefficient decreases, the absorption decreases, and the transmission increases. It has also been confirmed by (Ghosh and Das, 2014) that a significant portion of the food absorbs when interacting with gamma rays. It is thought-provoking that gamma rays cause such changes in food. Food has not become radioactive by this interaction. But it has interacted with radiation and absorbed it. In addition, studies have shown that irradiation causes changes in protein, fat, carbohydrate, and vitamin values in food (Ayhan, 1992; Villavicencio et al., 2000; Karadag and Gunes, 2005; Abdelwhab et al., 2009; Mudibu et al., 2012; Sarker et al., 2014; Mirhabibi et al., 2016; Yılmaz and Ulger, 2016; Vahapoglu et al., 2022). In the study conducted by (Abdelwhab et al., 2009), it was determined that there were changes in the protein, fat, carbohydrate, fiber, mineral, and vitamin values of irradiated dry beans. Similar determinations have been shown in different studies for products such as soybean, cowpea, and corn (Villavicencio et al., 2000; Mudibu et al., 2012; Sarker et al., 2014; Mirhabibi et al., 2016; Vahapoglu et al., 2022). The occurrence of such changes in food and the use of irradiation for mutation purposes in plant breeding studies are proof that the effect of gamma rays cannot be neglected (Well et al., 2022; Yasmin and Arulbalachandran, 2022). When genetically modified organisms (GMO) are considered, irradiation has the effect of disrupting the original structure of the product or organism, just like GMO processes.

Although food irradiation is considered suitable for food preservation, it needs more research in terms of the health of living things (Wen-Chieh, 2005; Atasever and Atasever, 2007; Demirci and Güner, 2008; Oguzhan, 2013; Durmaz and Sancak, 2014; Akakce and Cam, 2019; Mshelia et al., 2022). Because no matter how important food preservation is, a result that will not be beneficial for a living thing makes no sense. While evaluating food irradiation, the radiation dose is taken into account, but the amount of radiation absorption of the product is also very important. The main theme in this study is not food irradiation, but investigating how much food interacts with gamma rays. In this respect, only this interaction has been tried to be demonstrated by using a low-energy gamma source. Considering that the low-energy gamma will be less penetrating than the high-energy (for food irradiation), it is not difficult to estimate how large the interference in the radiation will be. In this study, considering the result that dry beans interact with gamma rays and absorb at least 10%, food irradiation is not a suitable process in terms health of living things.

3. Conclusions

In this study, the interaction with beans (legumes) was demonstrated using low-energy gammas. Very high-energy gamma rays are used in food irradiation. That is, when we talk about such interaction even with low energy ionized beam, we can say that this interaction can be big at high energy. As a result, in a substance exposed to ionizing radiation, some of the rays will remain in the substance. This is the result of interaction with ionizing radiation. As such, although it is claimed that food irradiation with ionizing radiation is safe, we can say that the amount of radiation absorption should be taken into account and the issue should be investigated further in terms of its effects on the health of living things.

Acknowledgments

The author thanks Dear Prof. Dr. Salih Zeki ERZENEOĞLU and Erzurum Atatürk University Science Faculty Physics Department for the research support of the study.

Statement of Conflict of Interest

The author has declared no conflict of interest.

Author's Contributions

The contribution of the author is 100%.

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